AN APPRAISAL OF JUDGING CRITERIA IN RELATION TO PERFORMANCE IN ELITE MALE AMATEUR BOXING

by

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Results: 1136

Discussion: 1527

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No portion of the work referred to in this Research Project has been submitted in support of an application for another degree or qualification of this, or any other University or institute of learning.

The project was supervised by a member of academic staff, but is essentially the work of the author.

Signed: James Latham

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Abstract

This study intended to appraise the features of the judging criteria of elite amateur boxing and determine the impact such features have on unanimous and split contest outcomes. Appraising eight offensive actions and their outcomes, the technical demands of open-class boxing from 93 male boxers (age: 24.4 ± 3.3 y; height: 176.1 ± 10.5 cm; body mass: 65.8 ± 12.9 kg) during 87 bouts of the 2016 Rio Olympic Games and 2017 World Amateur Boxing Championships were notated using computerized software. A 3 (round) x 4 (outcome) repeated measures ANOVA and Bonferroni-adjusted post-hoc statistical analyses were adopted. Twenty-five performance parameters differed between unanimous winners and losers, but only four between split winners and losers. Unanimous winners landed more punches than unanimous losers in total (P = 0.002) and in round 1, 2 and 3 (all P = 0.000). They also landed a higher percent of very successful punches than unanimous losers in total (P = 0.001) and in round 1 (P = 0.005), 2 (P = 0.027) and 3 (P = 0.02). Unanimous losers threw a greater percentage of air punches than unanimous winners per bout (P = 0.000) and in round 1 (P = 0.006), 2 (0.000) and 3 (P = 0.002). Unanimous winners landed a greater percentage of straight, hook, and uppercut punches thrown with the lead hand (P = 0.007, 0.000 and 0.049 respectively) and straight punches thrown with the rear hand (P = 0.003) than unanimous losers. Split winners landed a greater percentage of total punches than split losers in round 1 (P = 0.006) and 3 (P = 0.047). Judges use several performance indicators to assess superiority between boxers, albeit the technical disparity between split winners and losers is marginal compared to unanimous winners versus losers. This study proposes that the number of punches landed, punch accuracy and technical and tactical superiority all have an important influence during unanimous outcomes, but when judges are split on choosing the winner of a contest, only punch accuracy separates the two boxers.

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1. Introduction

Performance analysis concerns the systematic investigation and quantification of sporting performance to develop an understanding of sport and the requirements for success (Hodges & Franks, 2002; McLean, Salmon, Gorman, Read & Solomon, 2017). Whilst team sports have received extensive scrutiny, combat sports have received less attention (Thomson, Lamb & Nicholas, 2013). However, where boxing is considered, recent research has attempted to appraise the activity profile of amateur boxing and elucidate the technical differences between winning and losing performances (Davis, Benson, Pitty, Connorton & Waldock, 2015; Davis, Benson, Waldock & Connorton, 2016; Davis, Wittekind & Beneke, 2013), enhancing our understanding of the sport, with previous research failing to comprehensively quantify technical elements of a contest, instead providing only a selection of performance characteristics associated with success (Smith, 2006; Smith et al., 2001).

Examining winning performances of Egyptian national-level amateur boxers, El-Ashker (2011) found that winners had a greater punch output and landed, on average, more punches per round than losers, meanwhile Davis et al. (2015) found winners to have a greater punch accuracy in round 3 and landed a higher number of rear-hooks in rounds 2 and 3. Despite this, discriminating between winners and losers in elite amateur boxing appears to be difficult, whereas the discrimination of boxers of a novice or national level is larger (Davis et al., 2013; Slimani et al., 2017). Such a finding is consistent with several observations within a range of combat sports (Chaabene et al., 2014; Miarka et al., 2016).

Compounding the assessment of the sport, the Amateur International Boxing Association (AIBA) tend to implement rule changes, the latest of which included the removal of head guards and the adoption of the 10-point must system (TPMS) used in professional boxing (Bianco et al., 2013). The pre-2013 scoring mechanism meant boxers were awarded an unlimited amount of points for landing a punch with 'sufficient force' on the target area of the opponent (Davis et al., 2017; Thomson et al., 2013). The current impressionistic judging system is based on the following criteria: number of quality punches landed on the target area of the opponent, domination of a bout by technical and tactical superiority and competitiveness (AIBA, 2017). In absolute terms, punches per round have decreased since the changes (65.2 vs 62.7), with many techniques that were dominant pre-2013, including rear hand, rear hook and uppercut punches less frequent an occurrence (Davis et al., 2017). Due to the new scoring system, longer straight punches are now preferred by boxers, leading to the adoption of a more 'in-jab-out' strategy (Davis et al., 2017). Furthermore, defensive movements and increased foot movement have been shown to be key determinants of successful performances, possibly explained by the "greater threat of a knockdown or knockout" (Davis et al., 2017, p. 8). These suggestions, coupled with a high number of backhands, propose a successful attacking strategy conflicting with previous arguments that rear hook punches discriminate winning and losing (Davis et al., 2015). Importantly, the authors reported that the accuracy of punches thrown, rather than the total number of punches landed, discriminated between winning and losing performances (Davis et al., 2017). This has been supported by Dunn, Humberstone, Iredale, Martin and Blazevich (2017), and Wandee and Benjapalakom (2018), with the former finding winners to punch with greater accuracy compared to losers (33 vs 23%), as well as

throwing less air punches (17 vs 27%). Using a regression analysis, Dunn et al. (2017) found punch accuracy and movement index (ratio of time spent bouncing to stepping) to correct classify 85% (n = 19) of bout outcomes. Such data suggest that superiority (technical and tactical) and competitiveness are influenced by observational cues independent of the number of punches landed alone. However, research has not yet defined, nor quantified, 'technical and tactical superiority' or 'competitiveness', nor examined whether performance actions can be useful in determining sprecific contest outcomes (unanimous/split) instead of simply winning or losing.

Olympic boxing was classified as a subjective event by Balmer, Nevill and Lane (2005), since the majority of Olympic bouts are decided by officials rather than by knockout (approximately 86%), but changes to the scoring system should, by rule, mean contests are subjectively judged as opposed to objectively judged pre-2013 (Davis et al., 2017). Due to limits on how much information the human brain can process, sports judged by the subjective evaluation of performance are vulnerable to bias (Boen, Van Hoye, Vanden Auweele, Feys & Smits, 2008). At present, the inter-judge agreement in boxing is yet to be investigated, although judging consistency in Muay Thai has been examined by Myers, Nevill and Al-Nakeeb (2010), concluding that the application of a well-defined judgment criteria is responsible for the agreement between judges. Multiple systematic judging biases have been identified within sport, including order bias (Kramer, 2017), conformity bias (Myers, Nevill & Al-Nakeeb, 2012), nationalistic bias (Myers, Balmer, Nevill & Al-Nakeeb, 2006) and the 'halo effect' (Findlay & Ste-Marie, 2004). Firstly, order bias can exist through the sequential order of information affecting the manner in which information is processed by the human brain (Mussweiler, 2003). Research has found two main effects: a

primacy effect and a recency effect (Morgan & Rotthoff, 2014). A primacy effect is evident when the performance of the first individual or group receives a better score from a judge (Morgan & Rotthoff, 2014) whereas the facilitative effect of occupying a late position in a serially occurring sequence, observed in the judging of international figure skating (Bruine de Bruin, 2005, 2006) and Olympic diving (Kramer, 2017), results in a recency effect. Damisch, Mussweiler and Plessner (2006) observed a sequential order effect at the 2004 Athens Olympic Games, in which a gymnast's score for a routine was influenced by the previous performance. In boxing, it is plausible judges perceive the higher quality of work during an exchange to be the boxer who either initiated or finished the attack, regardless of what occurred in the middle of the sequence, thus also being an example of inattentional blindness. In the absence of attentional processes, attention may be diverted to other objects or stimuli, causing an individual to fail to notice important actions. When boxing judges' focus on the punches thrown and landed by a particular boxer, secondary errors may be present, such as punches thrown and landed by the opponent, or other aspects of the bout such as defensive movements and ring domination.

Combat sports can display social conformity, which is explained by judges being influenced by social pressure from the crowd and as a result, modifying their judgement (Myers et al., 2012). Indeed, spectators, by cheering for attacking movements regardless of the outcome, increase judging ambiguity via the number of false positives (an unsuccessful punch deemed successful) and false negatives (a successful punch deemed unsuccessful) a judge perceives (Di Felice & Marcora, 2014). Moreover, the impact of spectator behaviour on judgements of combat sports officials is potentially greater than that of team sports officials due to the close distance between fans and the ring, termed the

proximity effect (Myers & Balmer, 2012).

Given previous research has largely preceded the changes to the scoring system, the universal subjectivity of boxing and the ambiguous nature of the sport's judging criteria, an appraisal of officials' judgments is warranted. The purpose of this study is to determine the impact each criteria feature has on contest outcome and establish whether they differ between unanimous and split decisions, thus increasing boxers and coaches' awareness of what judges 'score for' during a contest. It is expected that the study will confirm judging is multifaceted and result in an increased transparency of the scoring system used in elite male amateur boxing.

2. Methods

Participants

A sample of 174 performances of 93 elite male boxers (age: 24.4 ± 3.3 y, stature: 176.1 ± 10.5 cm, body mass: 65.8 ± 12.9 kg) competing over 20 final, 36 semi-final and 31 quarter-final bouts of the 2016 Rio Olympic Games and the 2017 Hamburg World Amateur Boxing Championships were analyzed. A G*Power calculation was used to determine the required sample size (see Appendix 3). The performances were distributed across all 10 weight classes, ranging from light flyweight (49 kg) to super heavyweight (91+ kg) and were grouped as 'unanimous winner', 'split winner', 'split loser' and 'unanimous loser' dependent on the judges' decision. All bouts consisted of 3 x 3 minute rounds, interspersed by a one-minute break. Bouts were excluded from the study if they did not last the full duration due to either a technical knockout, walkover or stoppage due to an injury. Retrospective institutional ethical approval was granted by the Faculty of Medicine, Dentistry and Life Sciences Ethics Committee at the University of Chester.

Procedures

The footage was originally recorded using a single video camera (Sony Hi-8, Berks, UK). The bouts were analysed using Dartfish TeamPro software (version 8.0, Switzerland), at quarter speed (12.5 fps) or frame-by-frame when necessary. For each boxer, performance events were analysed using a bespoke 'tagging' template (Figure 1) in a sequential manner (Figure 2), in order of boxer, punch type, punch target, punch outcome and description.

Figure 2.1. Dartfish 'tagging' template for the coding of offensive actions.

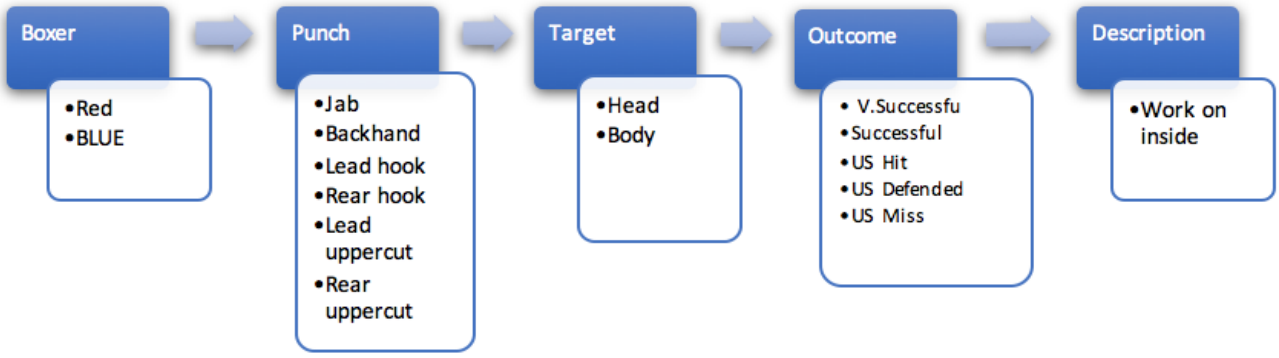

Figure 2.2. A schematic representation of how offensive actions were recorded.

The template included eight offensive movements, detailing whether the movement was made with the lead or rear hand with a straight, hook or uppercut technique. Each offensive action was further notated with regard to its intended target (head, body) and outcome (very successful, successful, unsuccessful defended, unsuccessful hit, unsuccessful miss). For definitions of each offensive movement and outcome, the reader is referred to Appendix 5. Defensive movements were not specified, instead punches missed due to a defensive action were notated with an 'unsuccessful defended' outcome. Punches labelled

‘unsuccessful defended’ and ‘unsuccessful miss’ were grouped as punches missed. Additional actions or events occurring in the contest were also notated; the round and its duration, and information such as the winner and score of the contest and each round. For boxers adopting an ‘orthodox’ stance, the left and right hands are the lead and rear hands respectively, whilst the opposite is applied with a ‘southpaw’ stance.

As per AIBA rules available online (AIBA, 2017), no information is provided for the judging criteria, but for the purpose of this study, definitions (see Appendix 4) have been created following consultation with an AIBA qualified referee and experiernced performance analyst (England Boxing, 2017).

Reliability Analysis

A bout was selected at random and analysed in full by the lead researcher on two separate occasions to determine intra-operator reliability. Moreover, the analysis of the same contest by an experienced performance analyst was used to document inter-operator reliability analysis. The methods of Cooper, Hughes, O’Donoghue and Nevill (2007) were used to quanitfy the intra- and inter-operator reliability, generating a statistic for each boxer individually and likewise each performance indicator (see Appendix 6).

Statistical Analysis

Data were analzyed using IBM SPSS Statistics (version 24) and are expressed as mean ± SD. Normality was assessed using a Kolmogorov–Smirnov test and homogeneity of variance was analysed using a Levene test. A 3 (round; first, second and third) x 4 (outcome; unanimous winner, split winner, split loser and

unanimous loser) repeated measures ANOVA was used to assess for differences for each variable, using round and outcome as within and between factors, respectively. Mauchly's test was performed to assess for assumptions of sphericity, with the Greenhouse-Geisser correction being used if sphericity was violated. Relevant post-hoc tests (paired samples t-test – repeated measures; Unpaired samples t-test – independent samples) were applied where necessary. Bonferroni adjustments were applied when appropriate. Cohen's effect sizes (*d*) were reported with the magnitude of effects considered small (0.2), medium (0.5) and large (0.8). Statistical significance was set at $P < 0.05$.

3. Results

The judges' decision on winners and losers did not agree with punches landed in 19 out of 87 bouts (22%). Of the 54 bouts ending in unanimous points decision, winners landed more punches than losers in 48 (89%), whereas 61% (*n* = 20) of split decision winners landed more punches than their losing counterparts (Table 1).

Table 3.1. Punches landed differential in relation to outcome (Mean ± SD).

	Punches landed differential
Winners who landed more punches (*n* = 68)	23.7 ± 17.1
unanimous winners who landed more punches (*n* = 48)	25.0 ± 17.4
split winners who landed more punches (*n* = 20)	19.8 ± 16.1
Losers who landed more punches (*n* = 19)	17.1 ± 10.7
split losers who landed more punches (*n* = 13)	17.6 ± 11.9
unanimous losers who landed more punches (*n* = 6)	16.0 ± 8.6

A main effect for the number of punches thrown was found between R2 and R3 ($t(173) = 2.651$, $P = 0.09$, $d = 0.12$) but no significant outcome effect existed ($F(3,170) = 0.546$, $P > 0.05$, $\eta^2_p = 0.10$). Regardless of group, a main effect was detected for punches landed between R2 and R3 ($t(173) = 3.766$, $P = 0.000$, $d = 0.2$). Unanimous winners landed significantly more punches per bout compared to unanimous losers ($P = 0.02$). Significant differences were found for punches landed between unanimous winners and unanimous losers in R1 ($t(53) = 4.754$, $P = 0.000$, $d = 0.54$), R2 ($t(53) = 5.992$, $P = 0.000$, $d = 0.61$) and R3 ($t(53) = 6.251$, $P = 0.000$, $d = 0.64$), whilst unanimous winners landed more punches than split losers in all three rounds (R1: $t(32) = 2.137$, $P = 0.04$, $d = 0.28$; R2: $t(32) = 3.038$, $P = 0.005$, $d = 0.46$; R3: $t(32) = 4.342$, $P = 0.000$, $d = 0.62$).

Table 3.2. Attacking movements in relation to round and outcome (Mean ± SD).

	Total	Round 1	Round 2	Round 3
Total punches				
unanimous win	217.7 ± 72.2	71.5 ± 25.5	74.1 ± 27.2	71.7 ± 24.7
split win	207.9 ± 62.8	69.3 ± 20.8	71.5 ± 22.5	67.1 ± 24.7
split loss	214.6 ± 60.7	74.2 ± 24.1	72.2 ± 20.3	68.2 ± 29.3
unanimous loss	202.0 ± 69.7	67.9 ± 26.6	67.8 ± 25.6	66.0 ± 24.8
Total punches landed				
unanimous win	75.6 ± 33.8*	24.4 ± 12.6*†	26.4 ± 13.2*†Ψ	24.6 ± 11.6*†Ψ
split win	67.1 ± 25.0	23.8 ± 9.0*	23.8 ± 10.3	20.1 ± 8.3
split loss	61.6 ± 22.5	21.4 ± 8.8	21.4 ± 8.0	18.5 ± 8.0
unanimous loss	55.2 ± 27.8	18.1 ± 10.7	19.2 ± 10.6	17.9 ± 9.2
Punches landed (%)				
unanimous win	34.5 ± 8.9*†	33.6 ± 11.9*†	35.4 ± 10.4*†	34.0 ± 9.2*†Ψ
split win	32.2 ± 7.4*	34.7 ± 9.6*†λ	32.7 ± 6.5*	30.2 ± 9.1†
split loss	28.7 ± 6.5	28.8 ± 8.0	29.9 ± 8.0λ	26.9 ± 7.9
unanimous loss	26.7 ± 6.8	26.1 ± 8.8	27.5 ± 7.4	27.0 ± 9.0
Very successful punches (%)				
unanimous win	2.3 ± 1.8*	2.3 ± 2.5*†	2.2 ± 2.2*	2.4 ± 2.8*†
split win	2.7 ± 2.0*	2.7 ± 2.7*	3.2 ± 2.2*	2.1 ± 2.2
split loss	1.9 ± 1.5	1.6 ± 2.2	2.4 ± 2.4	1.7 ± 1.6
unanimous loss	1.3 ± 1.4	1.1 ± 1.8	1.4 ± 1.8	1.4 ± 1.8
US defended (%)				
unanimous win	12.9 ± 9.2	14.8 ± 11.8	12.0 ± 9.6	11.9 ± 9.1
split win	12.2 ± 9.5	13.9 ± 10.5	12.4 ± 10.7	10.7 ± 9.1
split loss	14.3 ± 10.0	16.2 ± 11.1	14.0 ± 10.7	11.8 ± 10.1
unanimous loss	13.0 ± 9.4	14.7 ± 12.0	12.2 ± 10.1	12.0 ± 9.4
US hit (%)				
unanimous win	25.3 ± 8.9	22.1 ± 10.3	26.3 ± 10.4	27.0 ± 10.8
split win	26.9 ± 8.0	22.6 ± 9.0	26.5 ± 8.9	31.9 ± 11.2
split loss	27.8 ± 7.4	25.2 ± 8.5	26.7 ± 9.4	32.4 ± 9.7
unanimous loss	26.7 ± 8.0	23.9 ± 10.2	25.5 ± 9.3	29.9 ± 13.0
US miss (%)				
unanimous win	26.9 ± 9.0*	29.4 ± 11.2*	26.4 ± 10.2*	26.5 ± 10.3*
split win	28.0 ± 8.0*	28.9 ± 12.9	28.3 ± 8.6	27.6 ± 7.4
split loss	28.9 ± 9.1	27.9 ± 10.8*	29.0 ± 10.3	28.8 ± 9.5
unanimous loss	34.1 ± 10.4	35.1 ± 11.7	33.9 ± 11.6	32.4 ± 9.4
Total thrown to head				
unanimous win	185.7 ± 66.2	61.4 ± 24.6	62.5 ± 23.9	61.9 ± 21.9
split win	174.1 ± 57.6	56.1 ± 18.3	60.1 ± 20.7	57.1 ± 22.5
split loss	184.8 ± 52.5	64.2 ± 21.4	63.2 ± 18.4	57.9 ± 16.9
unanimous loss	165.0 ± 62.6	54.8 ± 25.5	55.9 ± 21.8	54.2 ± 21.3
Total thrown to body				
unanimous win	34.5 ± 16.6	11.5 ± 6.4	13.0 ± 8.4	11.4 ± 7.2
split win	37.2 ± 20.8	13.8 ± 8.8	13.0 ± 7.2	10.8 ± 6.9
split loss	32.8 ± 17.8	11.7 ± 7.3	10.4 ± 7.0	11.2 ± 7.1
unanimous loss	40.0 ± 18.5	14.6 ± 8.0	12.6 ± 7.2	13.4 ± 8.1
Punches landed to head (%)				
unanimous win	30.4 ± 8.7*†	29.6 ± 11.8*†	31.7 ± 9.9*†	29.8 ± 9.2*†
split win	29.7 ± 7.4*	31.2 ± 10.8*†	29.6 ± 7.8*	29.0 ± 8.5*†
split loss	25.8 ± 6.8	25.0 ± 7.8*	27.4 ± 9.1	23.8 ± 6.9
unanimous loss	22.1 ± 6.1	20.4 ± 8.9	22.7 ± 6.8	23.2 ± 7.7
Punches landed to body (%)				
unanimous win	47.8 ± 15.9	47.4 ± 23.0	46.6 ± 18.7	47.2 ± 26.9
split win	44.8 ± 14.2	48.7 ± 20.8	46.7 ± 17.2	36.2 ± 23.4
split loss	44.2 ± 17.9	45.7 ± 23.1	40.0 ± 24.6	41.9 ± 24.0
unanimous loss	40.4 ± 14.6	42.3 ± 19.7	41.2 ± 20.0	37.8 ± 22.8

* = significant difference ($p<0.05$) to unanimous loss, † = significant different ($p<0.05$) to split loss, Ψ= significant difference ($p<0.05$) to split winner, λ= significant difference to round 3.

Unanimous winners landed more punches than split winners in R2 (t(32) = 2.350, P = 0.025, d = 0.23) and R3 (t(32) = 3.837, P = 0.001, d = 0.45). Split winners landed a greater percentage of total punches than split losers in R1 (t(32) = 2.914, P = 0.006, d = 0.67) and R3 (t(32) = 2.066, P = 0.047, d = 0.38). A main effect for round was found (F(2,340) = 3.076, P = 0.026, η^2_p = 0.021) with split winners (t(32) = 2.724, P = 0.01, d = 0.48) and split losers (t(32) = 2.1, P = 0.44, d = 0.38) landing a lower percentage of total punches from R1 to R3 and R2 to R3, respectively.

Discriminating between winners and losers included very successful punches, with both unanimous and split winners landing a significantly greater percentage of total punches than unanimous losers per bout (both P = 0.001) and in R1 (t(53) = 2.938, P = 0.005, d = 0.54; t(32) = 2.503, P = 0.018, d = 0.72, respectively) and R2 (t(53) = 2.268, P = 0.027, d = 0.37; t(32) = 2.424, P = 0.021, d = 0.84, respectively). Unanimous winners also had a higher percentage of very successful punches landed than unanimous losers in R3 (t(53) = 2.389, P = 0.02, d = 0.41), and split losers in R1 (t(32) = 2.168, P = 0.038, d = 0.29) and R3 (t(32) = 2.606, P = 0.014, d = 0.31).

A main round effect for the percentage of total punches with an unsuccessful defended outcome (F(2,340) = 14.709, P = 0.000, ES = 0.08) was detected. Post-hoc paired samples t-tests revealed the percentage of unsuccessful defended punches to decrease between R1 vs R2 (t(173) = 3.809, P = 0.000, d = 0.22), R1 vs R3 (t(173) = 4.746, P = 0.000, d = 0.30) and R2 vs R3 (t(173) = 1.691, P = 0.093, d = 0.09). A main effect for unsuccessful hit punches as a percentage of total punches was found between rounds (F(2,340) = 37.01, P = 0.000, η^2_p = 0.179), reporting significant increases from R1 to R2 (t(173) = 3.942, P = 0.000, d = 0.30), R1 to R3 (t(173) = 7.743, P = 0.000, d =

0.62) and R2 to R3 (t(173) = 4.749, P = 0.000, d = 0.35) respectively. Regarding air punches as a percentage of total punches, significant differences were found between unanimous losers and unanimous winners (P = 0.000), and unanimous losers and split winners (P = 0.019). Unanimous losers threw more air punches as a percentage of total punches than unanimous winners in R1 (t(53) = 2.862, P = 0.006, d = 0.49), R2 (t(53) = 4.147, P = 0.000, d = 0.70) and R3 (t(53) = 3.302, P = 0.002, d = 0.60), and split losers in R1 (t(32) = 2.284, P = 0.029, d = 0.14).

Punch accuracy for shots thrown to the head was significantly greater for unanimous winners in all three rounds when compared to unanimous (R1: t(53) = 5.099, P = 0.000, d = 0.89; R2: t(53) = 6.536, P = 0.000, d = 1.06; R3: t(53) = 4.374, P = 0.000, d = 0.78) and split (R1: t(32) = 2.916, P = 0.006, d = 0.46; R2: t(32) = 2.849, P = 0.008, d = 0.45; R3: t(32) = 4.8, P = 0.000, d = 0.73) losers. Split winners had a higher punch accuracy to the head than split losers in R1 (t(32) = 2.643, P = 0.013, d = 0.66) and R3 (t(32) = 2.970, P = 0.006, d = 0.67). Regardless of group according to the judges' decision, boxers landed less body punches (percentage of total body punches) in R3 than R1 (t(173) = 2.315, P = 0.022, d = 0.20). Despite this, unanimous winners maintained body punch accuracy between R1 and R3 (47.4 ± 23.0 vs 47.2 ± 26.9 respectively).

Table 3.3. Attacking movements in relation to outcome (Mean ± SD).

	Unanimous win	Split win	Split loss	Unanimous loss
Total straight lead	92.5 ± 45.2	79.9 ± 32.3	83.0 ± 38.2	76.8 ± 33.1
Straight lead landed (%)	34.4 ± 12.7*	30.9 ± 10.0	28.6 ± 9.1	27.5 ± 10.2
Total straight rear	62.2 ± 22.9	63.8 ± 21.2	65.9 ± 25.0	59.0 ± 21.5
Straight rear landed (%)	36.8 ± 12.1*	32.8 ± 10.5	31.6 ± 8.8	29.4 ± 10.8
Total lead hook	38.5 ± 19.4	36.4 ± 20.7	41.2 ± 18.0	40.4 ± 19.7
Lead hook landed (%)	29.9 ± 12.7*	31.2 ± 13.5*	25.1 ± 11.8	20.1 ± 11.0
Total rear hook	16.1 ± 12.7	15.2 ± 14.0	16.2 ± 12.7	18.4 ± 17.0
Rear hook landed (%)	26.5 ± 21.3	30.2 ± 19.6	24.3 ± 15.6	20.7 ± 17.4
Total lead uppercut	3.8 ± 4.3	4.8 ± 7.0	5.3 ± 7.0	4.8 ± 8.1
Lead uppercut landed (%)	27.9 ± 32.6*	23.0 ± 29.6	21.9 ± 30.6	12.9 ± 23.4
Total rear uppercut	9.5 ± 10.0	10.6 ± 8.5	7.4 ± 7.6	8.2 ± 9.7
Rear uppercut landed (%)	30.4 ± 27.2	30.9 ± 24.0	30.2 ± 29.1	26.7 ± 24.2

* = significant difference ($p<0.05$) to unanimous loss.

Discriminating between unanimous winners and losers included the movements that were higher for winners; percentage of straight lead ($P = 0.007$), straight rear ($P = 0.003$), lead hook ($P = 0.000$) and lead uppercut ($P = 0.049$) movements landed. Split winners had a higher accuracy when using the lead hook technique ($P = 0.000$).

Table 3.4. Ratio of punches missed to punches landed in relation to outcome (Mean ± SD).

	Unanimous win	Split win	Split loss	Unanimous loss
Punches missed to landed ratio	1.3 ± 0.6*	1.4 ± 0.7*	1.6 ± 0.7	2.0 ± 0.9

* = significant difference ($p<0.05$) to unanimous loss.

Movements that were higher for unanimous losers in comparison to unanimous and split winners; the ratio of punches missed to punches landed (*P* = 0.000 and 0.003 respectively).

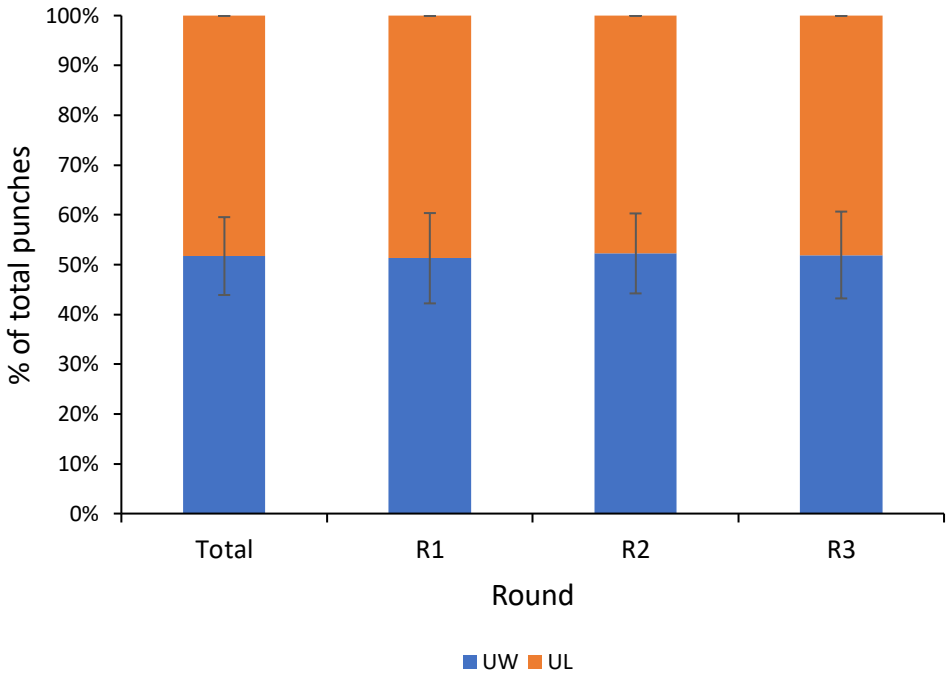

Figure 3.1. Relative percentage of punches per bout and per round for unanimous winners versus unanimous losers (Mean ± SD).

Of the combined total of punches thrown by each boxer, unanimous winners threw ~52% with unanimous losers throwing ~48%. They also throw a higher percentage of the total punches in R1, R2 and R3, albeit marginally (~51 vs ~49, ~52 vs ~48 and ~52 vs ~48, respectively).

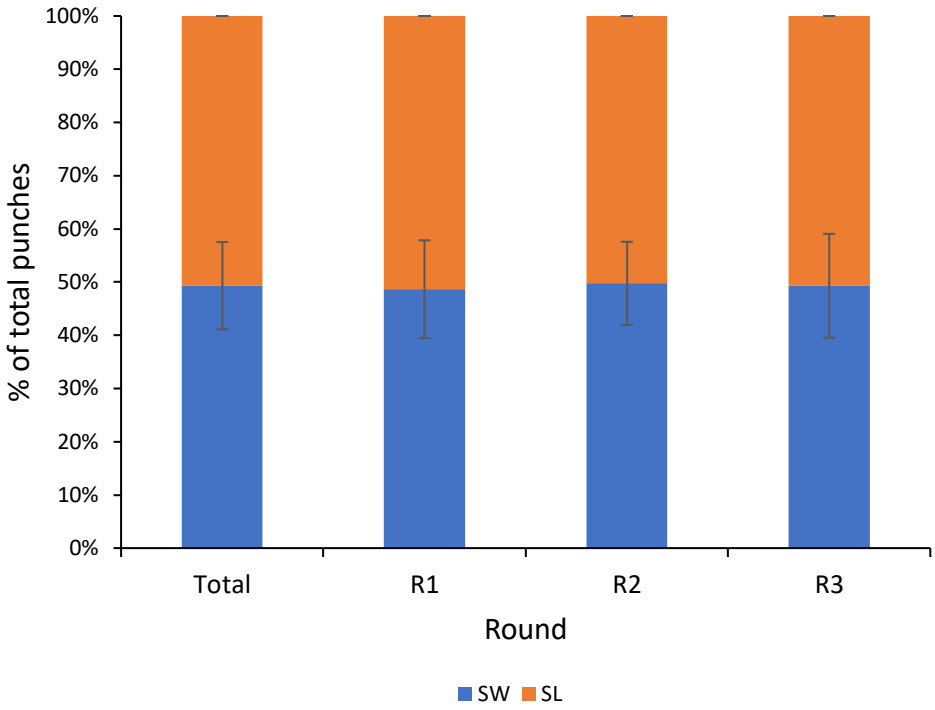

Figure 3.2. Relative percentage of punches per bout and per round for unanimous winners versus unanimous losers (Mean ± SD).

Of the combined total of punches thrown by each boxer, split winners threw ~49% with unanimous losers throwing ~51%. They threw a lower percentage of the total punches in R1 and R3, albeit marginally (both ~49 vs ~51).

4. Discussion

The current study is the first to propose definitions of each judging criteria and provides original data with respect to the different types of contest outcome (i.e. unanimous and split). Supporting previous research which has explored the technical actions of amateur boxing since the introduction of the TPMS, the analyses described above confirm the sport to be a complex environment (Thomson & Lamb, 2016), requiring a range of technical-tactical skills (Davis et al., 2017; Dunn et al., 2017).

Regardless of contest outcome, the number of punches thrown and landed decreased between R2 and R3, inconsistent with the findings of Davis et al. (2017) and Dunn et al. (2017). This may be explained by an increased fatigue index as a bout progresses, consistent with the observations of Dunn et al. (2017), who reported that boxers perceived a greater performance decrement (on a 5-point Likert scale), induced by fatigue, in R3 than R2 (2.7 ± 1.6 vs 2.2 ± 1.1, respectively). This suggests boxers employ pacing strategies to mitigate the effect of fatigue, including dropping their guard and using an increased translational movement style. However, perceptual variables were not recorded in the current study and it remains unknown why punch output decreased towards the end of bout.

Independent of the judges' decision, the number of punches landed per round was 21.7 ± 9.8, comparable to that of Dunn et al. (2017), but lower than the value previously reported during a major male amateur boxing competition (Davis et al., 2017). Although unanimous winners landed a significantly greater

number of punches than unanimous and split losers in all three rounds, and split winners in R2 and R3, no significant differences existed between split winners and losers. Despite this, split winners, on average, landed ~6 more punches than split losers, in spite of throwing ~7 less. This accounted for a greater punch accuracy, which reached significance in R1 and R3. It was also found that unanimous winners had a significantly greater punch accuracy than unanimous losers per bout and in each of the three rounds (33.6 vs 26.1, 35.4 vs 27.5 and 34.0 vs 27.0, respectively). The observation that punch accuracy is pertinent in amateur boxing under the current scoring system is now established (Davis et al., 2017; Dunn et al., 2017). Under the previous scoring system, a high punch output relative to the opponent was commonly found to discriminate winning and losing performances (Davis et al., 2013; El-Ashker et al., 2011; Thomson & Lamb, 2016; Wandee & Benjapalakom, 2018), although punch accuracy amounted to the supposition of Thomson and Lamb (2016) that the computer-based scoring system encouraged both the quantity and *quality* of a boxer's actions. In summary, judges' subjective ratings of superiority are closely related to a fighter's efficiency, rather than instances where boxers land and miss at similar rates.

Competitiveness, of which one component is work rate, is the fourth aspect listed in the AIBA judging criteria and according to the results of the current study, has a negligible influence on a judges' decision. Affirming the previously discussed notion that total punches thrown does not explain contest outcome, the relative percentage of total punches thrown per round is almost equal between winning and losers, regardless of a unanimous or split decision. As a result, it appears judges' do not use competitiveness to asses fight dominance.

The current study is the first to consider ‘very successful’ as a punch outcome, with the majority of authors solely quantifying if a punch was successful and unsuccessful (Davis et al., 2017; Dunn et al., 2017; Thomas & Lamb, 2016), although it is noted that Thomson et al. (2013) described both successful and partially successful attacks. Anecdotally, experienced performance analysts and coaches have suggested very successful punches, as per Appendix 6, hold a heavier weighting than a punch with lesser force or less of an impact on the opponent. The findings of this study show unanimous winners landed a greater percentage of very successful punches than unanimous losers in all three rounds, when made relative to the number of total punches a boxer threw. Interestingly, split winners landed a higher ratio of very successful punches to total punches (2.7 vs 2.3). However, no statistical significance existed between split winner and losers, emphasising that technical actions in elite amateur boxing should be made relative to your opponent and specific contest outcome instead of grouping boxers into ‘winners’ and ‘losers’.

Previous studies highlighted that boxers prefer punching to the head than the body with a ratio of 5:1 (Davis et al., 2013, 2016). Following the 2013 rules changes, Davis et al. (2017) reported an increase in head punches, resulting in a ratio of 8:1. The authors postulated that due to the removal of headguards and the computerized scoring system, boxers have an increased desire to obtain a knockdown or knockout, thus targeting the head more frequently. However, the current study is in agreement with the two studies which analysed amateur boxing under the former rules, finding the ratio of punches to the head compared to the body was 5:1 (Davis et al., 2013, 2016). To date, research has failed to quantify punching accuracy when dependent on target (i.e. head or body). In the present

study, boxers landed ~27% and ~44% of punches to the head and body, respectively. It is proposed that due to the increasing defensive movements used in amateur boxing (Davis et al., 2017) and the increased risk of a knockdown or knockout, defensive actions such as blocking head punches are prioritized, thus boxers are more susceptible to body punches. Unanimous winners were significantly more accurate with head punches than unanimous losers in all three rounds, whereas split winners landed a higher percentage of head punches in R1 and R3 when compared to split losers. Consequently, head punching accuracy may be a primary focus in training given that judges' favour boxers who better perform this skill.

Within the definitions of the judging criteria, technical superiority is shown by "throwing effective jabs" (Appendix 4). Of the offensive actions, the results demonstrated the jab was the most frequent and is posited as being the most important punch type as it can set up more forceful attacks, as well as inflicting damage in its own regard (Hickey, 2006). These punches necessitate a lower delivery time, allowing an opponent less time to perform a defensive action (Piorkowski, Lees & Barton, 2011). Unanimous winners were more effective using the jab than unanimous losers (34.4 vs 27.5% respectively). Following the jab, lead hook, straight rear and rear hook techniques were thrown most frequently, regardless of contest outcome. Unanimous winners had a significantly greater accuracy with straight rear and lead hook punches than unanimous losers, and whilst split winners had a greater lead hook accuracy than unanimous losers, the accuracy of specific punches did not differ in comparison split losers. These punches possess a higher peak impact force and velocity at contact than

the job and are used to inflict a higher degree of damage to the opponent (Piorkowski et al., 2011; Smith, Dyson, Hale & Janaway, 2000).

Tactical superiority can be demonstrated by a boxer who causes his opponent to miss (Appendix 4). Previous research has shown no significant differences for the absolute number of total punches classified as missed between winners and losers, but suggest it is the frequency of air punches as a percentage of missed punches which discriminates success (Davis et al., 2017; Dunn et al., 2017). Consistent with this finding, the current study reported unanimous winners threw a lower percentage of air punches than unanimous losers per bout (26.9 ± 9.0 vs 34.1 ± 10.4), as well as lower values in all three rounds. The ratio of punches missed to landed significantly differed between unanimous and split winners when compared to unanimous losers, with misses consisting of punches classified as 'unsuccessful defended' and 'unsuccessful miss'. Reducing the amount of air punches thrown should be a primary objective of a successful attacking strategy in an attempt to positively influence a judge's assessment of contest superiority.

Although the current study is the first to define the judging criteria in elite amateur boxing, aspects of both technical (e.g. throwing effective combinations) and tactical (e.g. neutralizing the style and stance of the opponent) superiority are absent from the analyses. Future research should also examine whether winning boxers initiate exchanges or counter more often, possibly confirming whether a sequential order bias is present in the subjective evaluation of boxing performance.

Approximately one in five contests resulted in the winner not corresponding to the amount of successful punches, corroborating the findings of Davis et al. (2017). This result confirms judging is multi-faceted in relation to winning a bout, and the presence that multiple criteria are used to evaluate performance (AIBA, 2017). The technical disparity between unanimous winners and losers is evident, however, contests in which the technical actions of the two boxers are similar, judging is proposed to be more difficult. Alongside the current judging criteria in amateur boxing, accuracy appears to be central to a judges' perception of a contest, and more important than overall assertiveness or volition (i.e. the total number of punches thrown), a component of 'competitiveness'.

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Appendix 1: Written permission to use video footage

Chris Connelly
GB Boxing
English Institute of Sport
Coleridge Road
Sheffield
S9 5DA

Dear James, Re: Consent letter

With regards to the contribution you are making to GB Boxing in your studies to appraise judging criteria in relation to performance in elite male amateur boxing and in direct response to your request (below). On behalf of GB Boxing I would like to confirm permission to use all video footage and tagging data files associated to the 2017 AIBA World Championships across quarter-final, semi-final and final bouts which we have provided to you.

'I am writing to ask your permission to use the video footage from the 2017 AIBA World Championships and the tagging data files from the quarter-final, semi-final and final bouts across all the male weight divisions. All data provided and results collected and treated according to the Data Protection Act (1998) and will be kept strictly confidential as individuals from the footage will not be identified when results are written up or used in any subsequent report or publication. All information gathered will be fed back to you to use at your disclosure with the coaches and boxers at GB Boxing'

Yours Sincerely

Chris Connelly
Senior Performance Analyst
GB Boxing – English Institute of Sport

Appendix 2: Ethical approval

Approval 2017/18

Faculty of Medicine, Dentistry and Life Sciences
Research Ethics Committee

frec@chester.ac.uk

Tuesday, 31st July 2018

James Michael Latham
14 Leonard Street
Chester
Cheshire
CH1 4BW

Dear James,

Study title: An appraisal of judging criteria in relation to performance in elite male amateur boxing.
FREC reference: 1470/18/JML/SES
Version number: 1

Thank you for sending your application to the Faculty of Medicine, Dentistry and Life Sciences Research Ethics Committee for review.

I am pleased to confirm ethical approval for the above research, **provided** that you comply with the conditions set out in the attached document, and adhere to the processes described in your application form and supporting documentation.

The final list of documents reviewed and approved by the Committee is as follows:

Document	Version	Date
Application Form	1	June 2018
Appendix 1 – List of References	1	June 2018
Appendix 2 – Summary CV for Lead Researcher	1	June 2018
Appendix 3 – Risk Assessment	1	June 2018
Appendix 4 – Written permission(s) from the relevant organisations to undertake the research (e.g. to use collected data for research purposes)	1	June 2018
Appendix 5 – External supervisor summary C.V.	1	June 2018
Appendix 6 – Operational definitions for key performance indicators	1	June 2018
Appendix 7 – Tuition fees invoice	1	June 2018
Appendix 8 – Permission to use video footage	1	June 2018
Appendix 9 – Interview schedule(s) or topic guide(s)	1	June 2018

Approval 2017/18

Response to FREC request for further information or clarification	1	July 2018

Please note that this approval is given in accordance with the requirements of English law only. For research taking place wholly or partly within other jurisdictions (including Wales, Scotland and Northern Ireland), you should seek further advice from the Committee Chair / Secretary or the Research and Knowledge Transfer Office and may need additional approval from the appropriate agencies in the country (or countries) in which the research will take place.

With the Committee's best wishes for the success of this project.

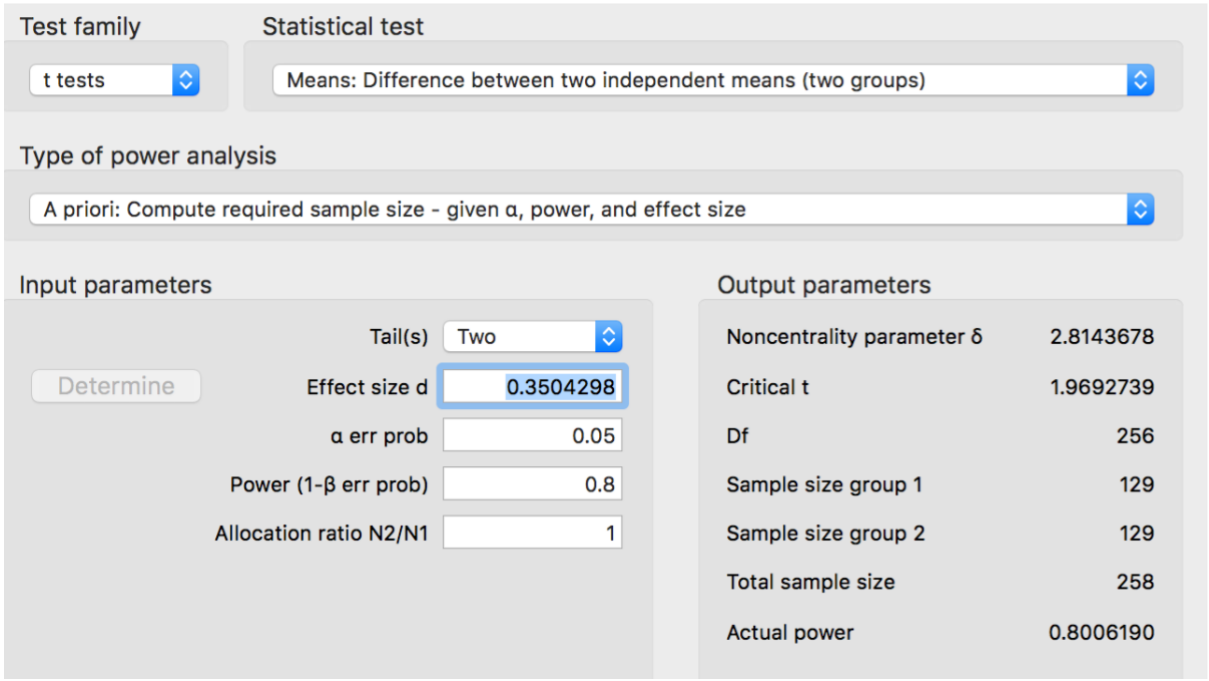
Yours sincerely,

Professor Stephen Fallows
Deputy Chair, Faculty Research Ethics Committee

Enclosures: Standard conditions of approval.

Cc. Supervisor/FREC Representative

Appendix 3. G*Power priori analysis



Appendix 4. Definitions of the judging criteria

Judging criteria	Definition
Technical superiority	A boxer who scores cleanly whilst not being caught by counter punches of an opponent. Shown by throwing effective combinations and effective counter jabs, standing his opponent off
Tactical superiority	A boxer who causes his opponent to miss and is therefore vulnerable to his punches. Demonstrated by a boxer neutralizing the style of the opponent e.g. orthodox vs southpaw
Competitiveness	Related to the activity/work rate of a boxer. Shown by a boxer who loses the previous round but comes back stronger in the following round

Appendix 5. Operational definitions for key performance indicators

Offensive movement	Definition
Jab	A straight punch from the lead hand that moves along the sagittal plane from anterior to posterior.
Backhand	A straight punch from the rear hand that moves along the sagittal plane from anterior to posterior.
Lead hook	A punch from the lead hand that moves along the transverse axis in a sideward 'sweeping' motion.
Rear hook	A punch from the rear hand that moves along the transverse axis in a sideward 'sweeping' motion.
Lead uppercut	A punch from the lead hand that moves along the sagittal plane and the longitudinal axis beginning with a downward projection and ending with an upwards projection.
Rear uppercut	A punch from the rear hand that moves along the sagittal plane and the longitudinal axis beginning with a downward projection and ending with an upwards projection.
Inverted jab	A straight punch from the lead hand that moves along the sagittal plane (the central visual line) from anterior to posterior with the arm in a supinated position when extended (palm facing upwards when arm is extended).
Inverted backhand	A straight punch from the rear hand that moves along the sagittal plane (the central visual line) from anterior to posterior with the arm in a supinated position when extended (palm facing upwards when arm is extended).

Offence outcome	Definition
Unknown	When there is no clear end point to the punch due to obstruction in the camera angle or from the frame rate of recording.
Unsuccessful miss	A punch that visibly misses the opponent completely and does not come into contact with any part of the opponent.
Unsuccessful defended	A punch that hits an opponent's arms or gloves when they are in a defensive position or movement. The opponent's arms or gloves in a defensive position may either parry the punch or be in a guard position (in the way of the head and body).
Unsuccessful hit	A punch which misses the target area but lands on another part of the opponent for example the arms or the back of the head or body. It can also be labelled if it lands on the target area but not in a scoring manner; the punch did not land with the knuckle part of a closed glove e.g. slaps or pushes, or when a punch lands on the target area but is described as work on inside.
Successful	A punch which visibly lands on the opponents target area with the knuckle part of a closed glove on any part of the front or sides of the head or body above the belt line of the opponent.
Very successful	A punch which visibly lands on the opponents target area with force enough to cause a noticeable reaction from the opponent boxer e.g. a knockdown or knockout, loss of motor functions, balance or coordination, count from the referee, extreme deviation of the head or body position and/or an emotional reaction from the boxer e.g. shouting, taunting.

Appendix 6. Reliability analysis

	Analyst 1	Analyst 2	Differences between scores	Agreement	% Error	Typical Error	CoV
US miss	67	66	1	No	1.5	1.0	1.1
US hit	145	145	0	Yes	0	0	0
US defended	81	86	5	No	5.8	3.0	4.0
Successful	114	119	5	No	4.2	2.5	3.0
Very successful	11	9	2	No	22.0	1.0	14.0
Total	418	425	7	No	1.6	2.5	1.2

	Analyst 1	Analyst 2	Differences between scores	Agreement	% Error	Typical Error	CoV
Jab	208	219	11	No	5.0	6.0	3.6
Backhand	139	149	10	No	6.7	5.0	4.9
Lead hook	31	32	1	No	3.0	1.0	2.0
Rear hook	15	12	3	No	25.0	1.5	15.7
Lead uppercut	9	8	1	No	13.0	1.0	8.0
Rear uppercut	17	17	0	Yes	0	0	0
Total	419	437	18	No	4.1	9.0	3.0

	Analyst 1	Analyst 2	Differences between scores	Agreement	% Error	Typical Error	CoV
Head	366	381	15	No	3.9	8.0	2.8
Body	53	56	3	Yes	5.4	2.0	3.9
Total	419	437	18	No	4.1	9.0	3.0

	Test	Re-test	Differences between scores	Agreement	% Error	Typical Error	CoV
US miss	67	66	1	No	1.5	0.5	1.1
US hit	145	145	0	Yes	0.0	0	0
US defended	81	82	1	No	1.2	0.5	0.9
Successful	114	116	2	No	1.7	1.0	1.2
Very successful	11	11	2	Yes	0.0	0	0
Total	418	420	2	No	0.5	1.0	0.3

	Test	Re-test	Differences between scores	Agreement	% Error	Typical Error	CoV
Jab	208	208	0	Yes	0	0	0
Backhand	139	141	2	No	1.4	1.0	1.0
Lead hook	31	31	0	Yes	0	0	0
Rear hook	15	14	1	No	7.1	0.5	4.9
Lead uppercut	9	9	0	Yes	0	0	0
Rear uppercut	17	17	0	Yes	0	0	0
Total	419	420	1	No	0.2	0.5	0.2

	Test	Re-test	Differences between scores	Agreement	% Error	Typical Error	CoV
Head	366	367	1	No	0.3	0.5	0.2
Body	53	53	0	Yes	0	0	0
Total	419	420	1	No	0.2	0.5	0.2